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Twofold hidden conformal symmetry of Kerr–Bolt black holes

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Previously we have shown that a four-dimensional Kerr–Bolt black hole in non-extremal and also in extremal cases could be described by a holographic two-dimensional (2D) conformal field theory (CFT) [Ghezelbash A M, Kamali V and Setare M R 2010 *Phys. Rev.* D **82** 124051; Setare M R and Kamali V 2010 *JHEP* **10** 074]. Motivated by recent work [Chen C M, Huang Y M, Sun J R, Wu M F and Zou S J 2010 *Phys. Rev.* D **82** 066004], we show that there is another holographic description for these black holes. The first description is called the J-picture, whose construction is based on the black hole angular momentum. The new description is called the Q-picture, whose constructions originate from the nut charge of the black hole. Similar to the previous cases [Ghezelbash A M, Kamali V and Setare M R 2010 *Phys. Rev.* D **82** 124051; Setare M R and Kamali V 2010 *JHEP* **10** 074], we show that this new picture for a low frequency limit of the wave equation of a massless charged scalar field in the background of a Kerr–Bolt black hole can be written as the Casimir of $SL(2, R)$ symmetry. Our result shows that the entropy of the black hole is reproduced by the Cardy formula. In addition, the absorption cross section is consistent with the finite temperature absorption cross section for a two-dimensional CFT.

Keywords: Kerr–Bolt back hole, holographic descriptions, hidden conformal symmetry, Cardy formula

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1. Introduction

According to the Kerr/conformal field theory (CFT) correspondence,[1] the microscopic entropy of a four-dimensional (4D) extremal Kerr black hole can be calculated by studying the dual chiral conformal field theory associated with the diffeomorphisms of the near horizon geometry of a Kerr black hole. The Kerr/CFT correspondence has been used in Ref. [2] to find the entropy of dual CFT for four and higher dimensional Kerr black holes in AdS spacetimes. The Kerr–Newman black holes in (A)dS spacetimes have been considered in Ref. [3]. This correspondence was firstly supported by the mach of the microscopic entropy counting with the macroscopic Bekenstein–Hawking entropy, and moreover supported by the agreement of the superradiant scattering amplitudes with the dual CFT prediction.[4–8]

Recently, Castro, Maloney and Strominger[9] have provided evidence that the physics of Kerr black holes might be captured by a CFT. The authors have discussed that the existence of conformal invariance in near horizon geometry is not a necessary condition, instead the existence of a local conformal invariance in the solution space of the wave equation for the propagating field is sufficient to ensure a dual CFT description. In the microscopic description, using the Cardy formula for the microscopic degeneracy, they reobtained the Bekenestein–Hawking entropy of the black hole. Due to the interest in these types of investigations, the holographic descriptions of other kinds of black holes have been studied in Refs. [10]–[25].

More recently, the authors of Ref. [26] (see also Ref. [27]), have shown that there are two different individual two-dimensional (2D) CFTs holographically dual to the Kerr–Newman black hole, coming from the corresponding two possible limits, the Kerr/CFT and Reissener–Nordstrom/CFT correspondences. These twofold holographic descriptions, called J-picture and Q-picture respectively for Kerr/CFT and Reissener–Nordstrom/CFT correspondences. The first description, in view of the angular momentum, has been discussed in Refs. [28] and [29] for a Kerr–Bolt black hole in non-extremal and extremal cases, respectively. In this paper, we will study the holographic description of a Kerr–Bolt black hole in non-extremal and extremal cases using the Q-picture.

The paper is organized as follows. In Section 2,

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we first review some basic properties of a Kerr–Bolt black hole, then we study the scattering process of a probe massless charged scalar field propagating in its background. In Section 3, we study the hidden conformal symmetry of this black hole by analysing the wave equation of the scalar field. Then we reproduce the Bekenstein–Hawking entropy by the Cardy formula of the dual conformal field. In Section 4, the absorption cross section is investigated and, finally, the last section is devoted to the conclusion.

2. Description of a Kerr–Bolt black hole

For a four-dimensional (4D) Kerr–Bolt black hole, with mass M, angular momentum $J = Ma$, and nut charge n, its metric takes the following form

$$\begin{aligned} \mathrm{d}s^2 = & -\frac{\Delta}{\rho^2}[\mathrm{d}t + (2n\cos\theta - a\sin^2\theta)\mathrm{d}\varphi]^2 \\ & + \frac{\sin^2\theta}{\rho^2}[a\,\mathrm{d}t - (r^2+n^2+a^2)\mathrm{d}\varphi]^2 \\ & + \frac{\rho^2\mathrm{d}r^2}{\Delta} + \rho^2\mathrm{d}\theta^2, \end{aligned} \tag{1}$$

where

$$\begin{aligned} \rho^2 &= r^2 + (n + a\cos\theta)^2, \\ \Delta &= r^2 - 2Mr + a^2 - n^2, \end{aligned} \tag{2}$$

which are exact solutions of the Einstein equations.[30]

The gauge field is

$$A = -\frac{nr}{\rho^2}[\mathrm{d}t + (2n\cos\theta - a\sin^2\theta)\mathrm{d}\varphi]. \tag{3}$$

There are two horizons located at

$$r_\pm = M \pm \sqrt{M^2 - a^2 + n^2}. \tag{4}$$

The angular velocity and the Bekenstein–Hawking entropy are respectively as follows:

$$\begin{aligned} \Omega_{\mathrm{H}} &= \frac{a}{r_+^2 + n^2 + a^2}, \\ S &= \pi(r_+^2 + a^2 + n^2). \end{aligned} \tag{5}$$

For a complex massless scalar field with charge q, the Klein–Gordon equation is

$$(\nabla_\mu + \mathrm{i}\,qA_\mu)(\nabla^\mu + \mathrm{i}\,qA^\mu)\Phi = 0. \tag{6}$$

The wave equation can be simplified by assuming the following form of the scalar field

$$\Phi(t, r, \theta, \varphi) = \exp(-\mathrm{i}\,\omega t + \mathrm{i}\,m\varphi)S(\theta)R(r), \tag{7}$$

where ω and m are the quantum numbers. In the non-extremal and low frequency limit $r_+\omega \ll 1$, the radial equation could be simplified as

$$\begin{aligned} & \partial_r((r-r_+)(r-r_-)\partial_r R(r)) \\ & + \left[\frac{(ma - \omega(r_+^2 + a^2 + n^2) + qnr_+)^2}{(r-r_+)(r_+-r_-)}\right. \\ & \left. - \frac{(ma - \omega(r_-^2 + a^2 + n^2) + qnr_-)^2}{(r-r_-)(r_+-r_-)}\right] R(r) \\ = & \ \lambda R(r). \end{aligned} \tag{8}$$

It would be interesting to study the radial equation in the extremal limit. In this case $\Delta = (r - r_+)^2$ and the radial equation could be simplified as

$$\begin{aligned} & \partial_r((r-r_+)^2)\partial_r R(r) + \frac{2[\omega(r_+^2 + a^2 + n^2) - ma - qnr_+](2\omega r_+ - nq)}{r - r_+} \\ & + \frac{[\omega(r_+^2 + a^2 + n^2) - ma - nqr_+]^2}{(r-r_+)^2} + CR(r) = 0. \end{aligned} \tag{9}$$

Following Ref. [26] there is twofold 2D conformal symmetry encoded in the solution space of the above equations. By assuming $q = 0$ in Eqs. (8) and (9), one can find a hidden conformal symmetry from the radial equation. This leads to a holographic description of the Kerr–Bolt black hole in non-extremal and extremal limits, as shown in Refs. [28] and [29], respectively. In addition, in the radial equations (Eqs. (8) and (9)) one may set $m = 0$ as well. This leads to another holographic description of the Kerr–Bolt black hole, which will be called Q-picture.

3. Hidden conformal symmetry in the Q-picture

In order to study the hidden conformal symmetry, we need to introduce the following coordinates for non-extremal black hole[9]

$$w^+ = \sqrt{\frac{r-r_+}{r-r_-}}\exp(2\pi T_{\mathrm{R}}^q\chi + 2n_{\mathrm{R}}^q t), \tag{10}$$

$$w^- = \sqrt{\frac{r-r_+}{r-r_-}}\exp(2\pi T_{\mathrm{L}}^q\chi + 2n_{\mathrm{L}}^q t), \tag{11}$$

$$y=\sqrt{\frac{r_+-r_-}{r-r_-}}\exp(\pi(T_{\rm R}^q+T_{\rm L}^q)\chi+(n_{\rm R}^q+n_l^q)t). \quad (12)$$

Following Ref. [9], we define left and right moving vectors by

$$H_1=\mathrm{i}\,\partial_+, \quad (13)$$
$$H_0=\mathrm{i}\left(\omega^+\partial_+ +\frac{1}{2}y\partial_y\right), \quad (14)$$
$$H_{-1}=\mathrm{i}((\omega^+)^2\partial_+ +\omega^+ y\partial_y - y^2\partial_-), \quad (15)$$
$$\bar{H}_1=\mathrm{i}\,\partial_-, \quad (16)$$
$$\bar{H}_0=\mathrm{i}\left(\omega^-\partial_- +\frac{1}{2}y\partial_y\right), \quad (17)$$
$$\bar{H}_{-1}=\mathrm{i}((\omega^-)^2\partial_- +\omega^- y\partial_y - y^2\partial_+), \quad (18)$$

for which each satisfies the $SL(2,R)$ algebra

$$[H_0,H_{\pm1}]=\mp\mathrm{i}\,H_{\pm1},\quad [H_{-1},H_1]=-2\,\mathrm{i}\,H_0, \quad (19)$$

and

$$[\bar{H}_0,\bar{H}_{\pm1}]=\mp\mathrm{i}\,\bar{H}_{\pm1},\quad [\bar{H}_{-1},\bar{H}_1]=-2\,\mathrm{i}\,\bar{H}_0. \quad (20)$$

The quadratic Casimir is

$$\begin{aligned}H^2=\bar{H}^2&=-H_0^2+\frac{1}{2}(H_1H_{-1}+H_{-1}H_1)\\&=\frac{1}{4}(y^2\partial_y^2-y\partial_y)+y^2\partial_+\partial_-. \end{aligned}\quad (21)$$

In terms of (r,t,ϕ), the Casimir becomes

$$\begin{aligned}H^2=&(r-r_+)(r-r_-)\frac{\partial^2}{\partial r^2}+(2r-r_+-r_-)\frac{\partial}{\partial r}\\&+\frac{r_+-r_-}{r-r_-}\left(\frac{T_{\rm L}^q-T_{\rm R}^q}{P}\partial_t-\frac{n_{\rm L}^q-n_{\rm R}^q}{\pi P}\partial_\varphi\right)^2\\&-\frac{r_+-r_-}{r-r_+}\left(\frac{T_{\rm L}^q+T_{\rm R}^q}{P}\partial_t-\frac{n_{\rm L}^q+n_{\rm R}^q}{\pi P}\partial_\varphi\right)^2, \end{aligned}\quad (22)$$

where $P=4(T_{\rm L}^q n_{\rm R}^q-T_{\rm R}^q n_{\rm L}^q)$. For the Q-picture description one should turn off the φ-direction momentum mode, by imposing $m=0$, and the radial equation in non-extremal limit, becomes

$$\begin{aligned}&\partial_r((r-r_+)(r-r_-)\partial_r R(r))\\&-\left[\frac{((nr_+/l)\partial_\chi+(r_+^2+a^2+n^2)\partial_t)^2}{(r-r_+)(r_+-r_-)}\right.\\&\left.+\frac{((nr_-/l)\partial_\chi-(r_-^2+a^2+n^2)\partial_t)^2}{(r-r_-)(r_+-r_-)}\right]R(r)\\&=\lambda R(r). \end{aligned}\quad (23)$$

Operator ∂_χ acts on the internal space of $U(1)$ symmetry of the complex scalar field and its eigenvalue is the charge of the scalar field $\partial_\chi\Phi=\mathrm{i}\,lq\Phi$. The parameter l is a varying constant, as we will see the central charges and the temperatures are parameterized by it. The radial equation is the Casimir operator Eq. (22), acting on Φ with the following identifications

$$\begin{aligned}n_{\rm L}^q&=\frac{r_++r_-}{4n^2},\quad n_{\rm R}^q=\frac{r_+-r_-}{4n^2},\\T_{\rm L}^q&=\frac{l(r_+^2+r_-^2+2(a^2+n^2))}{4\pi n^3},\\T_{\rm R}^q&=\frac{r_+^2-r_-^2}{4\pi n^3}. \end{aligned}\quad (24)$$

For the extremal black hole we should use the following conformal coordinate[31]

$$w^+=\frac{1}{2}\left(\alpha_1 t+\beta_1\chi+\frac{\gamma_1}{r-r_+}\right), \quad (25)$$
$$w^-=\frac{1}{2}\left(\exp(2\pi T_{\rm L}\chi+2n_{\rm L}t)-\frac{2}{\gamma_1}\right), \quad (26)$$
$$y=\sqrt{\frac{\gamma_1}{r-r_+}}\exp(\pi T_{\rm L}\chi+n_{\rm L}t). \quad (27)$$

Then the corresponding $SL(2,R)$ quadratic Casimir is

$$\begin{aligned}H^2=&\,\partial_r(\Delta\partial_r)-\left(\frac{\gamma_1(2\pi T_{\rm L}\partial_t-2n_{\rm L}\partial_\chi)}{\bar{A}(r-r_+)}\right)^2\\&-\frac{2\gamma_1(2\pi T_{\rm L}\partial_t-2n_{\rm L}\partial_\chi)}{\bar{A}^2(r-r_+)}(\beta_1\partial_t-\alpha_1\partial_\chi). \end{aligned}\quad (28)$$

where $\bar{A}=2\pi T_{\rm L}\alpha_1-2n_{\rm L}\beta_1$ and $\Delta=(r-r_+)^2$. In the Q-picture, we set $m=0$ and rewrite the radial equation as

$$\bar{H}^2R(r)=H^2R(r)=-CR(r), \quad (29)$$

then equation (9) becomes to

$$\begin{aligned}&\partial_r((r-r_+)^2)\partial_r R(r)\\&+\frac{2[\omega(r_+^2+a^2+n^2)-qnr_+](2\omega r_+-nq)}{r-r_+}\\&+\frac{[\omega(r_+^2+a^2+n^2)-nqr_+]^2}{(r-r_+)^2}+CR(r)=0. \end{aligned}\quad (30)$$

Equations (29) and (30) are equal to the following identification

$$\begin{aligned}\alpha_1^q&=-\frac{\gamma_1}{n^2},\quad n_{\rm L}^q=\frac{r_+}{2n^2},\\\beta_1^q&=\frac{2l\gamma_1 r_+}{n^3},\quad T_{\rm L}^q=\frac{l(r_+^2+a^2+n^2)}{2\pi n^3}. \end{aligned}\quad (31)$$

The left-temperature $T_{\rm L}^q$ and $n_{\rm L}^q$ are consistent with Eq. (24) in the extremal limit. In order to have a microscopic description of the black hole we need to determine the central charge of the dual CFT. We start from the near extreme black hole and consider its near-horizon geometry.[19] Similar to the Kerr case, we have the following coordinate transformation

$$r=\frac{r_++r_-}{2}+\epsilon r_0\hat{r},\quad r_+-r_-=\mu\epsilon r_0,$$

$$t=\frac{r_0}{\epsilon}\hat{t},\quad \varphi=\varphi+\frac{ar_0}{\epsilon(r_0^2+a^2+n^2)}\hat{t}, \tag{32}$$

then we have the near-horizon geometry of a near-extremal Kerr–Bolt black hole in the limit $\epsilon\to 0$[4,32,33]

$$\begin{aligned}\mathrm{d}s^2 =\ & \Gamma(\theta)\bigg(-\Big(\hat{r}-\frac{\mu}{2}\Big)\Big(\hat{r}+\frac{\mu}{2}\Big)\mathrm{d}\hat{t}^2\\ &+\frac{\mathrm{d}\hat{r}^2}{(\hat{r}-\frac{\mu}{2})(\hat{r}+\frac{\mu}{2})}+\alpha(\theta)\mathrm{d}\theta^2\bigg)\\ &\times\gamma(\theta)(\mathrm{d}\hat{\varphi}+\hat{P}\hat{r}\mathrm{d}\hat{t})^2,\end{aligned} \tag{33}$$

where

$$\begin{aligned}&\Gamma(\theta)=\frac{\rho_+^2r_0^2}{r_+^2+a^2+n^2},\quad \alpha(\theta)=\frac{r_+^2+a^2+n^2}{r_0^2},\\ &\gamma(\theta)=\frac{\sin^2\theta(r_+^2+a^2+n^2)^2}{\rho_+^2r_0^2},\\ &\hat{P}=\frac{ar_0^2(r_++r_-)}{(r_+^2+a^2+n^2)^2},\\ &\rho_+^2=r_+^2+(n+a\cos\theta)^2,\quad r_0^2=r_+^2+a^2+n^2.\end{aligned} \tag{34}$$

Through a translation $\hat{r}\to\hat{r}+\mu/2$ the above metric changes to the original form of the near-NHEK geometry given in Ref. [4]. We should emphasize that the singularities in the metric Eq. (1) as well as in Eq. (33) at the poles have a more complicated structure than that belonging to the familiar spherical coordinates for sphere S^2. These two string singularities should be removed by two separate identifications. Further identification is needed to remove the singularity at the horizon of Eq. (1) and all of the identifications must be compatible. Despite the detailed study of these three compatible identifications for Kerr–Bolt spacetimes,[30,34] there are no known explicit compatible identifications for Kerr–Bolt spacetimes with the cosmological constant. So, we proceed our calculation to find the central charge of dual CFT to the geometry of Eq. (33), which should be singularity-free after imposing compatible identifications. We leave studying the identifications of Eq. (1) for a future article.

The near horizon gauge field is

$$A_{[1]}=f(\theta)(\mathrm{d}\hat{\varphi}+\hat{p}\hat{r}\mathrm{d}\hat{t}) \tag{35}$$

with

$$f(\theta)=\frac{n(r_++a^2+n^2)(r_+^2-(a^2+n^2)\cos^2\theta)}{\rho_+^2a(r_++r_-)}. \tag{36}$$

In order to obtain central charge in Q-picture we need to uplift the geometry to five dimensions

$$\mathrm{d}s^2=\mathrm{d}s^2_{\mathrm{BH}}+(\mathrm{d}y+A_{[1]})^2, \tag{37}$$

where $\mathrm{d}s^2_{\mathrm{BH}}$ is the four-dimensional (4D) near horizon metric Eq. (1) and y is the fiber coordinate with period $2\pi l$. There is a degree of freedom in the gauge potential

$$A_{[1]}\to A_{[1]}+\varsigma\mathrm{d}\hat{\varphi} \tag{38}$$

with

$$\varsigma=\frac{n(r_+r_-+a^2)}{a(r_++r_-)}, \tag{39}$$

so that

$$A_{[1]}=(f(\theta)-\varsigma)\mathrm{d}\hat{\varphi}+f(\theta)\hat{p}\hat{r}\mathrm{d}\hat{t}. \tag{40}$$

Following Ref. [19], the central charge can be computed from five-dimensional (5D) generalization Eq. (37)

$$C^q_{\mathrm{R}}=C^q_{\mathrm{L}}=3\frac{\hat{p}\varsigma}{l}\int_0^{\phi}\mathrm{d}\theta\sqrt{\Gamma(\theta)\alpha(\theta)\gamma(\theta)}=\frac{6n^3}{l}. \tag{41}$$

Here we assume that the left and right central charges should be the same, similar to the Kerr case, then the CFT microscopic entropy matches the Bekenstein–Hawking area entropy of the Kerr–Bolt black hole

$$S^q_{\mathrm{CFT}}=\frac{\pi^2}{3}(C^q_{\mathrm{L}}T^q_{\mathrm{L}}+C^q_{\mathrm{R}}T^q_{\mathrm{R}})=\pi(r_+^2+a^2+n^2). \tag{42}$$

4. Scattering in Q-picture

As what we did for the J-picture in Refs. [28] and [29], we are going to study the scattering process to find further support for the duality. The solutions of Eq. (8), with $m=0$, also include the ingoing and outgoing modes

$$\begin{aligned}R^{\mathrm{in}}_q&=z^{-\mathrm{i}\,\alpha_q}(1-z)^{\beta_q}F(a_q,b_q,c_q;z),\\ R^{\mathrm{out}}_q&=z^{\mathrm{i}\,\alpha_q}(1-z)^{\beta^*_q}F(a^*_q,b^*_q,c^*_q;z).\end{aligned} \tag{43}$$

As like the case in the J-picture,

$$h^q_{\mathrm{L}}=h^q_{\mathrm{R}}=L+1. \tag{44}$$

Hence the coefficient a_q and b_q can be expressed in terms of the conformal weight

$$a_q=h^q_{\mathrm{R}}-\mathrm{i}\,\frac{\tilde{\omega}_{\mathrm{R}}}{2\pi T^q_{\mathrm{R}}},\quad b_q=h^q_{\mathrm{L}}-\mathrm{i}\,\frac{\tilde{\omega}_{\mathrm{L}}}{2\pi T^q_{\mathrm{L}}}, \tag{45}$$

the $\tilde{\omega}^q_{\mathrm{L}}$ and $\tilde{\omega}^q_{\mathrm{R}}$ are composed by frequencies (ω^q_{L}, ω^q_{R}), charges (q^q_{L}, q^q_{R}), and chemical potentials (μ^q_{L}, μ^q_{R}) as

$$\tilde{\omega}^q_{\mathrm{L}}=\omega^q_{\mathrm{L}}-q^q_{\mathrm{L}}\mu^q_{\mathrm{L}},\quad \tilde{\omega}_{\mathrm{R}}=\omega^q_{\mathrm{R}}-q^q_{\mathrm{R}}\mu^q_{\mathrm{R}} \tag{46}$$

with

$$\omega_{\rm L}^q = \frac{l\omega(r_+ + r_-)(r_+^2 + r_-^2 + 2(a^2+n^2))}{2n^3}, \quad q_{\rm L}^q = q,$$
$$\omega_{\rm R}^q = \frac{l\omega(r_+ + r_-)(r_+^2 + r_-^2 + 2(a^2+n^2))}{2n^3}, \quad q_{\rm R}^q = q,$$
$$\mu_{\rm L}^q = \frac{l(r_+^2 + r_-^2 + 2(a^2+n^2))}{2n^2},$$
$$n_{\rm R}^q = \frac{l(r_+ + r_-)^2}{2n^2}. \tag{47}$$

The absorption cross section can be read out directly from the conjugate charges in this picture

$$P_{\rm abs} \sim \sinh(2\pi\alpha_q) \mid \Gamma(a_q) \mid^2 \mid \Gamma(b_q) \mid^2 . \tag{48}$$

To see explicitly that $P_{\rm abs}$ matches the microscopic grey body factor of the dual CFT, we need to identify the conjugate charges, $\delta E_{\rm L}$ and $\delta E_{\rm R}$ defined by

$$\delta S_{\rm BH} = \delta S_{\rm CFT}^q = \frac{\delta E_{\rm L}^q}{T_{\rm L}^q} + \frac{\delta E_{\rm R}^q}{T_{\rm R}^q}. \tag{49}$$

From the first law of black hole thermodynamics

$$T_{\rm H}\delta S_{\rm BH} = \delta M - \Phi_{\rm H} n - \Omega_{\rm H}\delta J, \tag{50}$$

and

$$\delta E_{\rm L} = \omega_{\rm L}, \quad \delta E_{\rm R} = \omega_{\rm R}, \tag{51}$$

the absorption cross section can be expressed as

$$P_{\rm abs} \sim (T_{\rm L}^q)^{2h_{\rm L}-1}(T_{\rm R}^q)^{2h_{\rm R}-1} \times \sinh\left(\frac{\tilde{\omega}_{\rm L}^q}{2T_{\rm L}^q} + \frac{\tilde{\omega}_{\rm R}^q}{2T_{\rm R}^q}\right)\left|\Gamma\left(h_{\rm L}^q + {\rm i}\,\frac{\tilde{\omega}_{\rm L}^q}{2\pi T_{\rm L}^q}\right)\right|^2 \times \left|\Gamma\left(h_{\rm R}^q + {\rm i}\,\frac{\tilde{\omega}_{\rm R}^q}{2\pi T_{\rm R}^q}\right)\right|^2, \tag{52}$$

which is the finite temperature absorption cross section for 2D CFT.

5. Conclusion

In this paper, we have investigated the hidden conformal symmetry of extremal and non-extremal Kerr–Bolt black holes in a holographic Q-picture. We solved the wave equation of a massless charged scalar field in the background of Kerr–Bolt spacetimes in non-extremal and extremal cases respectively and found that in the near region, the wave equation can be written in terms of the $SL(2,R)$ quadratic Casimir. Our results show that the absorption cross section is consistent with the finite temperature absorption cross section for a 2D CFT. The entropy of the black hole is reproduced by the Cardy formula. So, in our interesting background a probe scalar field at low frequencies can exhibit two different 2D conformal symmetries in its equation of motion. Therefore, one can say that there are two different individual 2D CFTs holographically dual to the Kerr–Bolt black hole, coming from the corresponding two possible limits. Previously we have investigated the J-picture of these spacetimes in Refs. [28] and [29]. In the present paper we have considered the Q-picture. So we considered the charged scalar field with $m = 0$, where the radial part of the wave equation can be written again as the Casimir of $SL(2,R)_{\rm R} \times SL(2,R)_{\rm L}$. In these two different pictures, the expression of the central charges and the temperatures of the dual CFTs have different forms.

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